

Claims

What is claimed is:

1. A highly sensitive accelerometer for sensing acceleration in a direction perpendicular to a longitudinal axis of the sensor, the accelerometer comprising:
 - a rigid housing;
 - a mass pivotally attached to the housing;
 - an elastic support member aligned along the longitudinal axis and suspending the mass within the housing;
 - wherein at least a portion of the elastic support member comprises a transducer configured to measure a displacement of the mass within the housing in response to an acceleration along the direction.
2. The accelerometer of claim 1 further comprising a fixed mandrel rigidly attached to the housing wherein:
 - the mass comprises a floating mandrel; and
 - the elastic support member is wrapped about the fixed mandrel and the floating mandrel.
3. The accelerometer of claim 2 wherein the floating mandrel is pivotally connected to the housing by a hinge.
4. The accelerometer of claim 3 wherein the floating mandrel rotates about the hinge due to the acceleration to be sensed.
5. The accelerometer of claim 1 wherein the elastic support member comprises an optical fiber coil.
6. The accelerometer of claim 5 wherein movement of the mass induces in the fiber a corresponding variation in length of the optical fiber coil.
7. The accelerometer of claim 6 wherein the variation in the length is measured interferometrically.

8. The accelerometer of claim 1 further comprising an alignment assembly substantially preventing movement of the mass in a direction perpendicular to the direction of the sensed acceleration.
9. The accelerometer of claim 8 wherein the alignment assembly comprises a flexure member attached to the mass and the housing allowing movement of the mass in the direction of the sensed acceleration.
10. The accelerometer of claim 8 wherein the alignment assembly comprises a diaphragm.
11. The accelerometer of claim 10 wherein the alignment assembly comprises:
a pair of diaphragms each disposed on an end of an alignment rod; and
a bore positioned in each side of the housing, wherein the diaphragms are captured within the bore about the periphery of the diaphragms.
12. The accelerometer of claim 1 wherein the transducer comprises a strain gauge.
13. The accelerometer of claim 12 wherein the strain gauge is selected from the group consisting of: a fiber optic sensor, a piezoelectric device, a PVDF material and a resistive strain gauge.
14. The accelerometer of claim 12 wherein the transducer is a fiber optic Bragg grating.
15. A highly sensitive accelerometer for sensing acceleration in a direction perpendicular to the longitudinal axis of the sensor, the accelerometer comprising:
a rigid housing;
a mass pivotally attached to the housing;
a fixed mandrel attached to the housing;
at least one elastic support member axially aligned in the housing and wrapped around the fixed mandrel and the mass, the support member comprising a means for measuring rotation of the mass within the housing in response to an acceleration perpendicular to the longitudinal axis of the sensor.

16. The accelerometer of claim 15 further comprising at least one alignment means for substantially preventing movement of the mass in a direction perpendicular to the direction of the sensed acceleration.
17. The accelerometer of claim 15 wherein the floating mandrel is pivotally connected to the housing by a hinge.
18. The accelerometer of claim 15 wherein the means for measuring rotation comprises a means for measuring a change of length of the elastic support member.
19. The accelerometer of claim 18 wherein the means for measuring rotation comprises a means for interferometrically measuring a change of length of the elastic support member.
20. An apparatus for vertical seismic profiling comprising:
an optical fiber transmission cable; and
a plurality of accelerometers coupled to the earth and in optical communication with the optical fiber transmission cable and positioned in at least two orthogonal directions, each the linear accelerometer comprising:
a rigid housing;
a mass pivotally attached to the housing;
an elastic support member aligned along the longitudinal axis of the sensor and suspending the mass within the housing;
wherein at least a portion of the elastic support member comprises a transducer configured to measure displacement of the mass within the housing in response to an acceleration along a direction perpendicular to said longitudinal axis and to provide a light signal indicative of static and dynamic forces at an accelerometer location.
21. The apparatus of claim 20 further comprising an optical signal processor connected to the optical transmission cable providing seismic profile information based on the light signal.

22. The apparatus of claim 20 further comprising an array of the linear accelerometers coupled to the earth at a plurality of predetermined positions.
23. The apparatus of claim 20 wherein the plurality of accelerometers are coupled to the earth via an oil well casing, a bore hole, or an oil production tube.
24. The apparatus of claim 20 further comprising a fixed mandrel rigidly attached to the housing wherein:
- the mass comprises a floating mandrel; and
 - the elastic support member is wrapped about the fixed mandrel and the floating mandrel.
25. The apparatus of claim 24 wherein the floating mandrel is pivotally connected to the housing by a hinge.
26. The apparatus of claim 25 wherein the floating mandrel rotates about the hinge due to the acceleration to be sensed.
27. The apparatus of claim 20 wherein the elastic support member comprises an optical fiber coil.
28. The apparatus of claim 27 wherein movement of the mass induces in the fiber a corresponding variation in length of the optical fiber coil.
29. The apparatus of claim 28 wherein the variation in length is measured interferometrically.
30. The apparatus of claim 20 wherein each accelerometer further comprises an alignment assembly substantially preventing movement of the mass in a direction perpendicular to the direction of the sensed acceleration.
31. The apparatus of claim 30 wherein the alignment assembly comprises a flexure member attached to the mass and the housing allowing movement of the mass in the direction of the sensed acceleration.

32. The apparatus of claim 30 wherein the alignment assembly comprises a diaphragm.
33. The apparatus of claim 32 wherein the alignment assembly comprises:
a pair of diaphragms each disposed on an end of an alignment rod; and
a bore positioned in each side of the housing, wherein the diaphragms are captured within the bore about a periphery of the diaphragms.
34. The apparatus of claim 20 wherein the transducer comprises a strain gauge.
35. The apparatus of claim 34 wherein the strain gauge is selected from the group consisting of: a fiber optic sensor, a piezoelectric device, a PVDF material and a resistive strain gauge.
36. The apparatus of claim 34 wherein the transducer is a fiber optic Bragg grating
37. A method of detecting acceleration comprising:
providing a rigid housing having a mass disposed within the housing which is pivotably attached to the housing;
providing an elastic support member aligned with a longitudinal axis of the rigid housing and connected to the housing and the mass;
measuring a change in the length of the elastic support member caused by rotational displacement of the mass, the rotational displacement induced by an acceleration of the rigid housing in a direction orthogonal to the longitudinal axis.
38. The method of claim 37 wherein the elastic support member comprises an optical fiber.
39. The method of claim 38 wherein the measuring is performed interferometrically.
40. The method of claim 38 wherein the optical fiber further comprises a Bragg grating.

41. The method of claim 37 further comprising substantially preventing movement of the mass in a direction perpendicular to the predetermined direction.

41. The method of claim 37 further comprising substantially preventing movement of the mass in a direction perpendicular to the predetermined direction.